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Ship-Generated Waste Management in İstanbul Ports: An Analytical Methodology to Evaluate Waste Reception Performance (WRP)

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Abstract

Ship-generated pollutants constitute a significant portion of marine pollution, prompting the International Maritime Organization to regulate this issue. European countries have also adopted the 2000/59/EC directive on port reception facilities, and environmental performance indicators have gained prominence in European ports. This study examines two ports, Ambarlı and Haydarpaşa, located in İstanbul, Türkiye, a European Union candidate country. The research compares port size and computes their waste reception performance (WRP) indices: ship-based WRP, waste-type-based WRP, and waste-amount-based WRP. Additionally, statistical analysis with the Spearman correlation test, Kruskal-Wallis test, and Mann-Whitney U tests are applied to observe the relation between the number of ships and waste reception amounts. This study enhances ship-generated waste management using port performance indicators to mitigate pollution. The performance indices reveal that although Ambarlı's port size is larger than that of Haydarpaşa, the WRP of Haydarpaşa is significantly larger than that of Ambarlı. This difference can be attributed to the greater waste volume generated by general cargo ships compared with container ships. Given the differences between terminal types, it is evident that there is no "one size fits all" policy approach, and mitigation strategies need to be tailored to the characteristics of each port.

Keywords: Marine pollution, Port reception facilities, Ship-generated pollution, Waste management, MARPOL

1. Introduction

Marine pollution, a consequence of human activities, has precipitated significant ecological damage, hindering marine ventures such as fishing, imperiling human health, and curtailing recreational prospects [1]. Various factors contribute to this dilemma, from land-based pollutants to maritime endeavors [2-6]. Of these, maritime activities stand out, being responsible for almost 20% of global marine waste discharge [7]. As these activities intensify, the imperative to devise sustainable environmental management strategies becomes evident, compelling ports to augment their performance [8].

Driven by the sheer magnitude of maritime transport, with over 100,000 ships crisscrossing global waters [9], the marine environment has been inundated with a myriad of pollutants, ranging from oily residues and sewage to plastics and cargo residues [10]. Historically, these wastes were either discarded into the vastness of the seas or incinerated onboard. However, the tide turned with rising environmental concerns, compelling the International Convention for the

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Prevention of Pollution from Ships (MARPOL) to implement stringent waste reception guidelines [11]. Specifically, Annex V of this convention categorizes and imposes stringent limitations on various forms of ship-generated waste, as detailed in Figure 1. Certain disposals, under specific conditions, remain feasible, particularly in the waters of the Sea of Marmara (SoM) [11]. This paradigm shift is not just international; the European perspective on ship waste has similarly evolved. By 2020, ship waste had risen to the 6th position in environmental priorities as green port parameters, marking an increase from its 10th position in 2004 [12-15]. Notably, two studies that examined Turkish ports [16,17] revealed a distinctive emphasis on waste management as a crucial criterion for attaining green port status, surpassing the level of importance assigned to this criterion in European ports. Reinforcing this sentiment, the European Community introduced Directive 2000/59/EC, which endorses dedicated waste reception facilities in ports [18]. Riding this wave of environmental reform, countries, including Türkiye, have adjusted their marine waste disposal strategies to align with MARPOL and EU directives, as exemplified by Türkiye's embrace of the online Ship Waste Tracking System (GATS) for methodical ship waste declarations [19-21].

The narrative turns pressing when focusing on the SoM, especially when considering adverse events such as marine litter and alarming mucilage occurrences [22-26]. This study concentrates on its lens to two of SoM's ports, Ambarlı and Haydarpaşa, proposing a novel methodology for indices that evaluate ports' WRP. This initiative is aimed at monitoring, assessing, and mitigating ship-generated waste impact in the SoM, thereby contributing to its sustainable management. As the marine traffic, predominantly international, heightens its imprint on the region's pollution, the findings of this research will prove instrumental in charting a course for an environmentally sound maritime sector in the SoM.

In the subsequent sections, we will unpack the prevailing studies in our literature review, delineate our investigative approach in the methodology, probe into the specifics of Ambarlı and Haydarpaşa Ports in our case study, and conclude with insights and recommendations.

2. Literature Review

Ship-generated waste is a significant environmental concern in the domain of port reception facilities. Discharging waste at sea is highly undesirable, and port reception facilities are critical for preventing marine pollution [27]. Prior to the work of Carpenter and Macgill [28] on North Sea ports, port reception facilities were defined as one or more fixed, mobile, and/or floating facilities and could be categorized based on ownership type, operational changes, and contract rules. All of these measures are aimed at ensuring a significant reduction in marine pollution by providing adequate waste reception facilities [27]. The increasing complexity of maritime activities, coupled with their inherent environmental repercussions, has led to

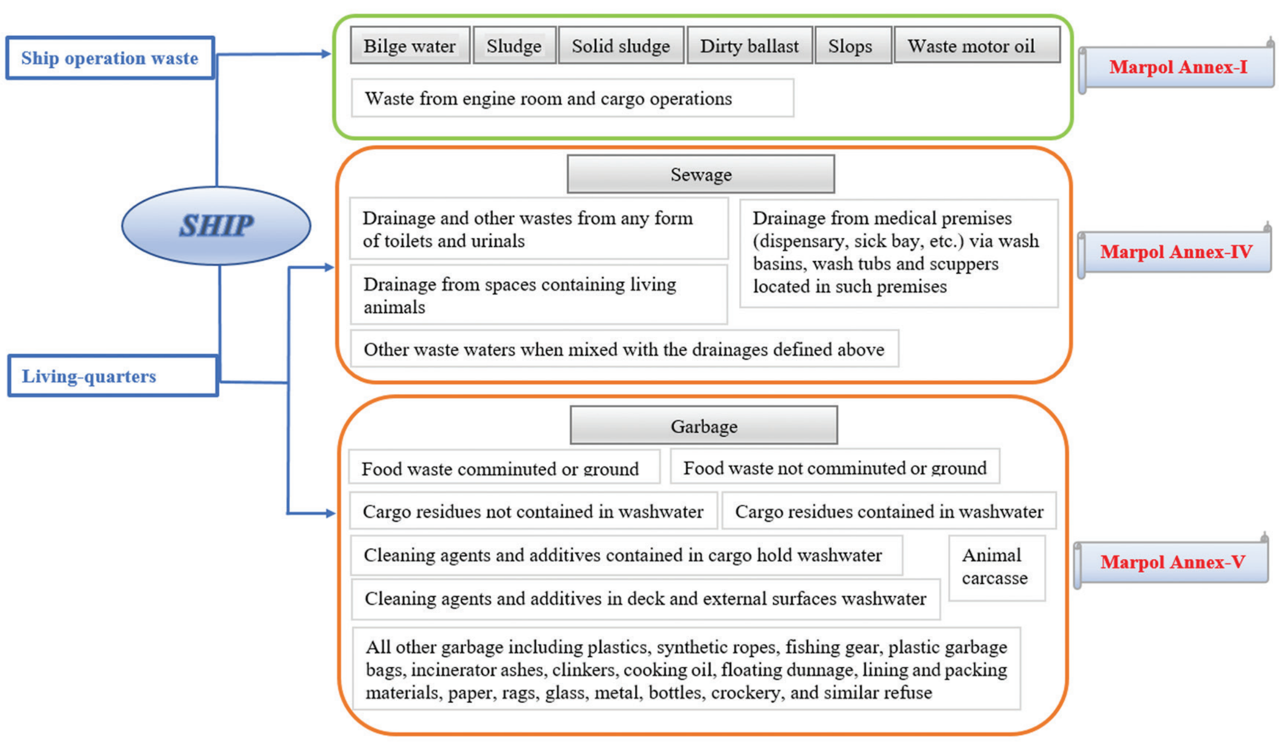

Figure 1. *Categorization of the ship-generated waste type within the framework of MARPOL 73/78 (based on [12,21])*

an enriched academic discourse around effective waste management systems between ship and port authorities. A noteworthy contribution comes from Di Vaio et al. [29], who proposed a novel approach based on environmental key performance indicators. This metric-oriented perspective is stated by Peris-Mora et al. [30], who designed an indicator framework to evaluate port environmental operations, notably referencing MARPOL 73/78/97 regulations. Mohee et al. [31] advanced this dialog by structuring a Port Waste Management System that, among other elements, encapsulates organizational paradigms, responsibilities, and goal-target-measurement parameters.

Ship waste, a nuanced subject, has often been categorized into two broad research categories: a) leaving-working-tourism and b) vessel operations-related studies. Delving deeper, tourism-centered investigations focus on passenger ships, including ferries and cruises. Notably, while constituting a mere 1% of total ships, cruise ships are responsible for an astonishing quarter of the total vessel waste, which is attributed to their multifaceted operations [32]. This proportion swells to 13% when ferry ships are included [33]. Consequently, the prominence of waste generated by passenger ships has been a recurrent theme in numerous academic explorations [32-38]. To quantify this, Ulnikovic et al. [37] conducted a comprehensive analysis, discovering that an individual typically produces 1 kg of solid waste daily. This sentiment is further stated by Beza et al. [39], who highlight a waste output of 3 kg/day per crew member in Greece. Onwuegbuchunam et al. [40] pivot the discourse toward vessel operations-related waste, splitting it into shipborne and cargo-related waste. They furnish empirical data illustrating that motorized cargo ships, tanker ships, and tugboats produce average volumes of 3.7 m^3, 4 m^3, and 3.5 m^3 of bilge water per service, respectively. Additionally, the multifaceted nature of ship waste has been quantitatively dissected by studies such as Zuin et al. [41], delineating the diverse types of waste produced annually. A pivotal study by Pérez et al. [42] adopted an analytical approach, correlating variables such as ship typology, age, and number of occupants to waste generation patterns. Their findings underscore the decisive role of ship size and onboard population in determining waste output, subsequently recommending a differentiated waste fee structure.

Waste disposal, especially sewage, has a profound environmental impact, with the potential to trigger marine eutrophication [36]. Despite regulatory measures such as MARPOL Annex IV [43], there remain stipulated conditions under which untreated sewage can be discarded, posing environmental hazards, especially in sensitive areas such as the SoM. Institutional responses to these challenges are noteworthy. The European Sea Ports Organization (ESPO) has pioneered environmental prioritization in European ports since 1998 [44]. Their Green Guide stands out as a robust blueprint that promotes waste management incentives and metrics. An evolution toward "Environmental Performance Indicators" in European ports is discernible, witnessing a 16% uptick between 2004 and 2013 [12]. ESPO's strategic port categorization [13] further accentuates environmental evaluation dynamics based on cargo handling volumes.

Despite the voluminous literature on European Union (EU) port reception facilities [29,37,42,45], there is a conspicuous paucity of research on Turkish ports [19,20]. This gap underscores the imperative for more comprehensive and localized studies in regions such as Türkiye to ensure holistic global advancements in marine waste management.

In the following sections, the methodological framework for this study is elaborated in Section 3, providing insight into data acquisition and analysis. Section 4 show cases an in-depth case study, illustrating the practical application of this methodology in a real-world context. Section 5 presents and analyzes our study findings within the broader academic landscape. Finally, the concluding section summarizes our key contributions and underscores the significance of our work.

3. Materials and Methods

3.1. Data Collection and Analysis

Waste reception and port size data for the Ambarlı and Haydarpaşa Ports serve as the foundation of this study. The waste reception data encompasses details about the number of ships and the amount of waste received, all

Figure 2. *Geographic location of Ambarlı and Haydarpaşa Ports*

sorted by the waste types delineated in MARPOL 73/78 (see Figure 2 and Tables 1 and 2). This information was sourced from ISTAC Inc., an entity under the Istanbul Metropolitan Municipality, and analyzed using the SPSS 29.00 statistical package. On the other hand, port size is gauged on the basis of cargo handling amounts as defined by [13], with categories ranging from less than 5 million tons to over 50 million tons Furthermore, the number of berthed ships is integrated as an additional determinant of port size. Both the volume of ship calls and the quantity of managed cargo at the mentioned ports are extracted from annual reports issued by the Ministry of Transportation and Infrastructure (MTI) of the Republic of Türkiye [46].

3.2. Proposed Methodology

The assessment of waste reception performance in ports can be effectively conducted using WRP indices, which provide valuable insights and indicators to evaluate the efficiency and compliance of waste management practices in accordance with the regulations outlined in MARPOL 73/78. The authors introduce a novel approach that involves the calculation of WRIs to evaluate and compare the efficiency and compliance of waste management practices across various ports while considering specific ship and cargo operations. To facilitate this assessment, a waste notification form is utilized, which encompasses eight distinct waste categories, as depicted in Figure 1, each designated by the corresponding notations provided in Table 1.

Table 1. *Ship-generated waste types*

Ship-generated waste (m^3/year)	Waste type code	Waste-type-based waste reception performance indices
Waste motor oil	w_1	Ps_1
Sludge	w_2	Ps_2
Slops	w_3	Ps_3
Bilge water	w_4	Ps_4
Dirty ballast	w_5	Ps_5
Sewage	w_6	Ps_6
Solid sludge	w_7	Ps_7
Garbage	w_8	Ps_8

Equation 1 outlines the methodology for determining the total waste reception amount in a port or terminal, achieved by aggregating the quantities of the eight waste categories.

$$W = \sum_{i=1}^{n=8} w_i \qquad (1)$$

where the calculation of the WRP indices in this study involves using the amount of each waste type (w_i), as shown in Table 2, received by the waste reception facility. To perform the performance analysis, four parameters are required

i. The number of ships berthed,

ii. The number of ships serviced by the waste reception facility, and

iii. The types and amounts of waste received (in cubic meters per year),

iv. the total waste reception amount (in cubic meters per year), and

v. The size of the port (measured by the amount of handled cargo in tons).

The ship-based waste reception performance indices (P_w) are then calculated using Equation 2, which determines the ratio of the number of ships that received waste reception services to the total number of ship calls.

$$Pw = \frac{s_w}{s_b} \qquad (2)$$

where the number of ships receiving the waste reception service (s_w) and the total number of ships berthed (s_b) are essential parameters for evaluating waste reception performance. Moreover, the amount of waste collected in each waste type serves as an important factor for classifying and assessing ports. Therefore, the waste-type-based waste reception performance indices (P_{si}) are expressed as shown in Equation 3.

$$Ps_i = \frac{w_i}{s_w} \text{ For } i = \{1\ldots,8\} \qquad (3)$$

Table 2. *Analysis of the difference between the number of ships served by the ports and the amount of waste collected*

Port	Statistical information	Number of vessels served	Amount of waste collected
Haydarpaşa Port	Mean ± std. deviation	654.17±105.01	6777.51±1312.42
	Median (min.-max.)	691.50 (490-763)	7253.24 (5121-8221)
Ambarlı Port	Mean ± std. deviation	693.00±77.62	4580.61±374.34
	Median (min.-max.)	679 (601-816)	4496.02 (4248-5205)
Sig.		0.818	0.004

where the variable "w_i" represents the quantity of each waste type received by the waste reception facility, while "s_w" corresponds to the number of ships that were provided with waste reception services. Within this framework, Equation 3 offers a calculation to categorize ports more specifically.

The computation of the waste amount-based waste reception performance indices is presented in Equation 4.

$$Ps = \sum_{i=1}^{n=8} Ps_i \quad i=\{1...,8\} \tag{4}$$

Additionally, Equation 4 is equal to Equation 5.

$$Ps = \frac{W}{s_w} \tag{5}$$

Port size is an additional parameter that is considered when evaluating waste reception performance, particularly with regard to the environmental indices of ports. This parameter encompasses both the amount of cargo handled and the number of ships berthed within a given year. It is important to observe the correlation between cargo handling and waste reception performance, as this can provide valuable insights into port performance.

$$P_p = \frac{x}{s_b} \tag{6}$$

where P_p is the port size parameter, x is the amount of cargo handled in a year, s_b is the number of ships berthed.

Calculations are performed in MATLAB for both Haydarpaşa and Ambarlı Ports. A comparative methodology was employed to evaluate the waste reception performance of these ports.

4. Case Study

The geographical location of the SoM makes the sea an attractive region for national and international ship transport [47]. The SoM is home to more than 30 international cargo terminals, 83 local piers for ferries, 8 marinas, and 50 fishing ports [48]. In this study, the authors selected the Ambarlı and Haydarpaşa Ports for analysis and evaluation purposes, which are known for their significant ship traffic. The Ambarlı and Haydarpaşa Ports were chosen because of their strategic importance within the SoM, serving as crucial hubs for national and international maritime trade. These ports not only handle a substantial volume of cargo but also play a pivotal role in the economic development of the İstanbul region and Türkiye as a whole. The Ambarlı and Haydarpaşa Ports are situated in the İstanbul region of the SoM. Specifically, the Ambarlı Port is in the western region of İstanbul, while the Haydarpaşa Port is situated at the entrance of the İstanbul Strait in the central region of İstanbul (see Figure 2).

Given their locations, the ship traffic around the Haydarpaşa Port is relatively more congested than that around the Ambarlı Port due to the high volume of ship traffic passing through the Istanbul Strait. Container ships constitute the primary vessels operating in the Ambarlı port. While the Turkish Republic State Railway (TCDD) manages the Haydarpaşa Port, private enterprises manage the Ambarlı Port [49].

In both Ambarlı and Haydarpaşa ports, ships generated waste reception service has been provided to ensure environmental sustainability and compliance with international regulations by ISTAC Inc., which is a corporation under the İstanbul Metropolitan Municipality responsible for waste receptions in the Ports of İstanbul [48]. In the management of waste reception services in İstanbul ports, including Ambarlı and Haydarpaşa, several procedures have been followed (see Figure 3). The waste

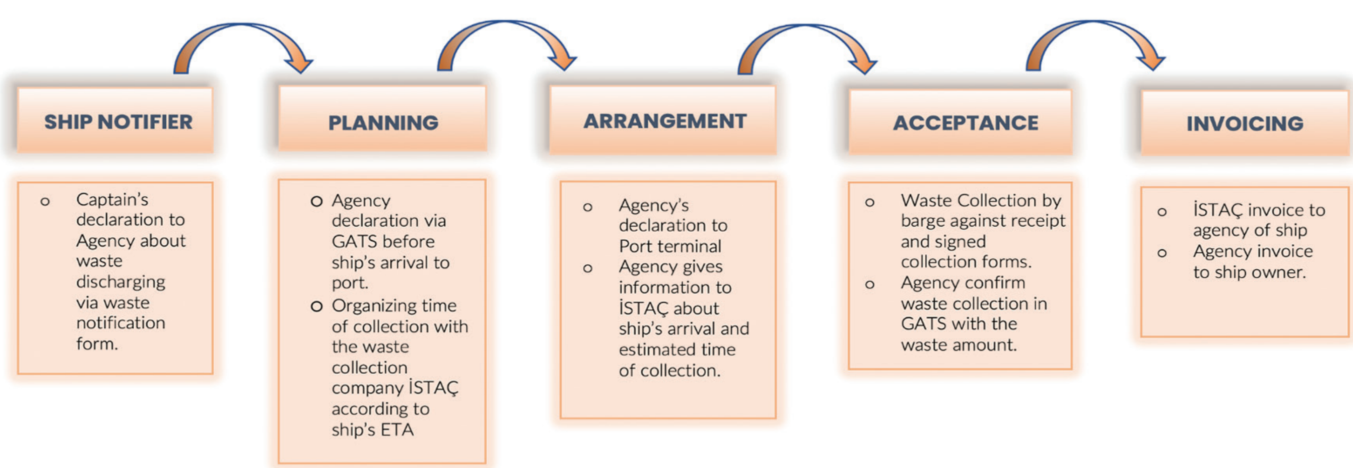

***Figure 3.** Waste reception process in the ports of İstanbul*

reception process begins with notification by ships [29]. The remaining procedures are given in Figure 3 are followed by the ship's agency.

5. Results and Discussion

Waste reception amount and number of ship calls in Ambarlı and Haydarpaşa ports are given in Figures 4 and 5. According to these graphs, the mainly discharged waste type is sludge in Ambarlı Port and bilge water in Haydarpaşa Port. Additionally, the waste reception amount in Ambarlı Port is lower than that in Haydarpaşa Port even if the number of ship calls in Ambarlı Port is higher than that in Haydarpaşa Port.

The proposed computation of waste reception performance provides quantitative outputs to compare ports based on their performance indices. Within this framework, Haydarpaşa Port shows higher ship-based waste reception performance than Ambarlı Port (see Figures 4 and 5), indicating that the waste reception service provided in Haydarpaşa Port is nearly 1.5-2 times higher than that provided in Ambarlı Port with respect to the number of ships berthed in both ports. This result shows that Haydarpaşa Port has a much more active ship-based waste reception performance. However, it should be noted that the higher rate at Haydarpaşa port is also related to the time between ships' berthings and sailing. If the handling operation is fast, the ship may not discharge its waste to the waste reception facility, resulting in the waste reception organization going over to the next port of call or potentially causing illegal discharges [51].

Ambarlı Port generally serves container ships [52], while Haydarpaşa Port has a more diversified ship portfolio. According to data from 2015, container cargo services were 1585419, 1169019, and 335576 Twenty-Foot Equivalent Unit (TEU) for Marport, Kumport, and Mardas terminals in Ambarli Port, respectively, and only 121641 TEU in Haydarpaşa Port [53]. Considering the cargo service speed of container terminals, time is more restricted compared with that of general cargo terminals. Nonetheless, a waste reception organization that does not delay the ship supports the efficiency of ship-generated waste control and management.

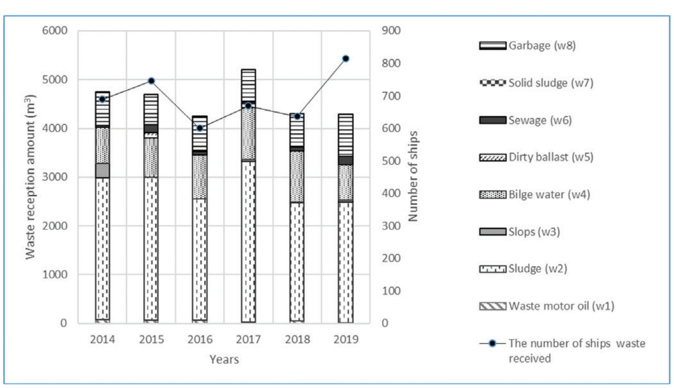

Figure 4. *Waste reception amount and the number of ship serviced in Ambarlı Port*

Another factor that can influence the time required for waste reception is the location of the garbage barges. The central location of Haydarpaşa Port enables faster waste reception organization, whereas delays in waste reception declaration can lead to postponement or cancelation of the operation. ISTAC, the waste management company, can compensate for late declarations in Haydarpaşa because of its easily accessible location, in contrast to Ambarlı Port. Moreover, waste reception can be efficiently organized if a waste reception declaration is made by the ship and the agency two days before the vessel's arrival (as shown in Figure 2). As known from ISTAC, Haydarpaşa Port is busy also waste reception operation of city ferries.

Figure 6 shows the P_w indices for Ambarlı and Haydarpaşa Ports. P_w is one of the important indicators to show the waste reception activity of the port per ship. Haydarpaşa Port provides significantly higher waste reception service between berthed ships. It can also be stated that ships in Haydarpaşa prefer waste reception organizations over those in Ambarlı.

The waste reception types graphs, including the P_{si} values, are presented in Figure 7, which illustrates that Haydarpaşa Port has a higher performance in waste type-based waste reception. The highest waste type received in Haydarpaşa Port is bilge water (w_4). In contrast, the highest waste reception type in Ambarlı Port is sludge (w_2), with sludge being the second highest received waste type at Haydarpaşa Port. Furthermore, the sludge reception indices of Ambarlı Port are 1.5 times higher than those of Haydarpaşa Port. Garbage is the third highest waste type, with garbage reception indices being the same in both ports (see Figure 5). As demonstrated in Pérez et al. [42], the amount of garbage is related to the number of people on board ships. However, no data are available regarding the number of separated and recycled wastes. Considering the plastic

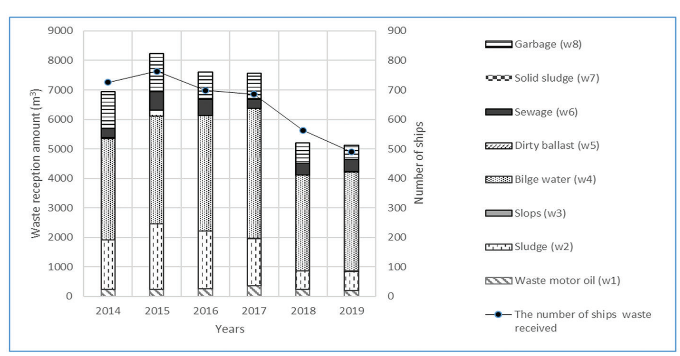

Figure 5. *Waste reception amount and number of ship serviced in Haydarpaşa Port*

threat in the region as estimated by Kaptan et al. [19], it is crucial to track the data on recyclable waste. Additionally, the separation and reception of recyclable waste onboard materials, such as plastic, metal, and glass, are significant in reducing marine litter pollution in the region.

The waste reception performances of both ports based on the amount of waste are presented in Figure 8. Despite the significant fluctuations in indices values from year to year, the indices values for Ambarlı Port range almost from 5 to 8, whereas those for Haydarpaşa Port range from 9 to 12. These findings show that the P values in Haydarpaşa Port surpass those in Ambarlı Port each year. Higher bilge water reception performance in Haydarpaşa than in Ambarlı is also related to the bilge water treatment technology and management of ships that call in Haydarpaşa and Ambarlı. The management of oily bilge water can change depending on each ship's amount of waste being treated, disposed at sea, or retained on board for delivery at port reception facilities, as stated by the report of CE DELFT and CHEW [54] for the European Maritime Safety Agency.

Puig et al. [12] used the parameters of port size defined by

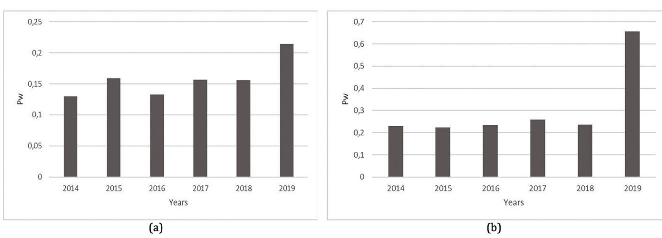

Figure 6. *Ship-based waste reception performance in Ambarlı Port (a) and Haydarpaşa Port (b)*

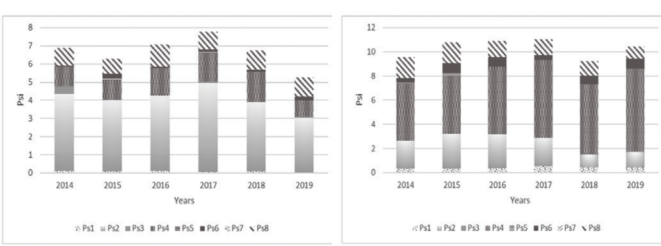

Figure 7. *Waste reception types for each ship-generated waste type in Ambarlı Port (a) and Haydarpaşa Port (b)*

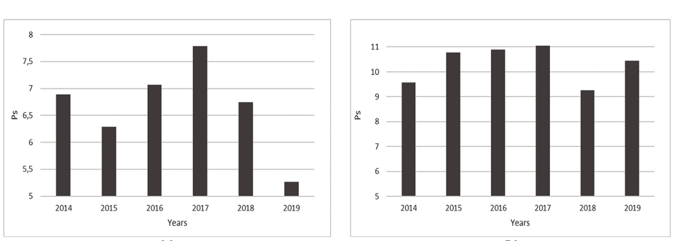

Figure 8. *Waste amount-based waste reception performance in Ambarlı Port (a) and Haydarpaşa Port (b)*

ESPO [14] to evaluate European ports. Based on the data (see Figure 9) from annual reports published by the MTI of the Republic of Türkiye [46], Ambarlı and Haydarpaşa ports

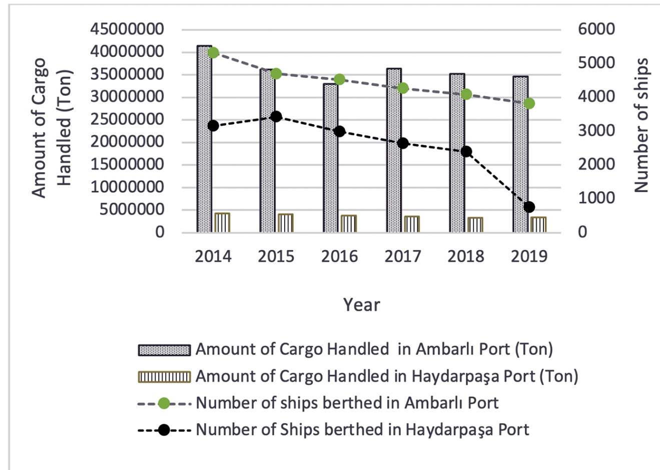

Figure 9. *Comparison of the amount of cargo handled and the number of ship calls between Ambarlı and Haydarpaşa Port (data received from [48]).*

were categorized into groups 3 and 1, respectively, according to ESPO [14] port size categorization. Figure 9 presents a comparison of these parameters between Ambarlı and Haydarpaşa Ports. The Ambarlı Port is significantly larger than the Haydarpaşa Port according to the port size values given in Figure 9. However, despite having lower operational activity in port size parameters, Haydarpaşa Port exhibits higher waste reception performance than Ambarlı Port. This inverse relationship is attributed to the difference in the type of serviced ships [42] in both ports. Moreover, as highlighted in the literature [55,56], a general cargo ship generates considerably more operational waste (garbage generated from the regular operation of a ship's main and auxiliary engines) during a voyage than a container ship of similar size, owing to its cargo, engines, and equipment. The findings of the study by Senarak [56] support this study as stated that general cargo ships have the highest impact on the amount of operational waste compared to container, Ro-Ro, and bulk carriers. Additionally, Carpenter [57] and Carpenter and Macgill [58] studied a survey based on 77 European ports to evaluate port reception facilities. Their results show that waste reception facilities are higher for general cargo ships than container ships.

6. Statistical Analysis

The data obtained at the end of the study were analyzed using the SPSS 29.00 statistical package program. During the analysis of the data, the Spearman correlation test, Kruskal-Wallis test, and Mann-Whitney U test, which are non-parametric tests, were used as they would show a skewed distribution due to the number of data being less than 30. Relationships between variables with two categories were analyzed using the Mann-Whitney U test. The Mann-Whitney U test was used for unrelated measurements to analyze whether the scores obtained from pairwise unrelated samples of Haydarpaşa Port and Ambarlı Port differ significantly from each other. If the variables are more than two, the relationships between the variables are analyzed using the Kruskal-Wallis test. The change over the years regarding the total number of berthing ships and the total amount of waste received was examined using the Kruskal-Wallis test. The average standard deviation, median, minimum, and maximum values, categorical data, frequency, and percentage values of the variables of the number of ships docking at Haydarpaşa and Ambarlı Ports, and the amount of waste received from the ships were examined (Table 2). The Spearmen correlation test was used to determine the relationships between the total number of berthing ships and the total amount of waste received, which are two numerical variables. A significance level of 0.05 was set in the interpretation of the results.

A statistically significant difference was found between the amount of waste collected and the ports (p<0.004). While the mean and standard deviation of the amount of waste collected in Haydarpaşa port is 6777.51±1312.42, the median value is 7253.24, the mean and standard deviation of the amount of waste collected in Ambarlı port is 4580.61±374.34, and the median value is 4496.02. The difference is statistically significant. The number of wastes collected in Ambarlı Port was found to be less than that collected in Haydarpaşa Port.

In Table 3, it has been examined whether the number of ships serving and the amount of waste collected differs from year to year. No statistically significant difference was found (p-values >0.005). The average and standard deviation of the number of vessels serving in 2014 was 707.50±26.16, the median value was 707.5, the average and standard deviation of the number of collected waste was 5843.03±1555.56, and the median value was 5843.03. The mean and standard deviation of the sample were 146.50±207.18, and the median value was 146.5. In 2019, the mean and standard deviation of the number of ships serving was 653.00±230.52, the median value was 653.00, the average and standard deviation of the number of collected waste was 4708.29±584.92, and the median value was 4708.29. The mean and standard deviation of the amount were 27.65±13.22, and the median value was 27.65. As we approached from 2014 to 2019, the number of ships serving and the amount of waste collected decreased.

Analyses were performed using non-parametric tests, since the number of data was less than 30. The Mann-Whitney U test was used to measure the difference between variables with two categories, and the Kruskal-Wallis test statistic was used in cases where there were more than two categories. Numerical data are shown with mean standard deviation median minimum and maximum values, and categorical data are shown with frequency and percentage values. The Spearman correlation test was used to examine the relationship between two numerical variables. The significance level was set at 0.05 for all tests.

A correlation coefficient (r) of 0.0 indicates no relationship, a value between 0.01 and 0.29 indicates a low level of relationship, a value between 0.3 and 0.7 indicates a moderate relationship, a value between 0.71 and 0.99 indicates a high level of relationship, and 1 indicates a perfect relationship. When Table 4 is examined, it is seen

Table 3. *Analysis of the difference between the number of ships served per year and the amount of waste collected*

Year	Statistical information	Number of vessels served	Amount of waste collected
2014	Mean ± std. deviation	707.50±26.16	5843.03±1555.56
	Median (min.-max.)	707.50 (689-726)	5843.03 (4743-6942)
2015	Mean ± std. deviation	754.50±12.02	6457.68±2494.76
	Median (min.-max.)	754.50 (746-763)	6457.68 (4693-8221)
2016	Mean ± std. deviation	649.50±68.59	5926.73±2372.97
	Median (min.-max.)	649.50 (601-698)	5926.73 (4248-7604)
2017	Mean ± std. deviation	677.00±11.31	6384.31±1667.63
	Median (min.-max.)	677.00 (669-685)	6384.31 (5205-7563)
2018	Mean ± std. deviation	600.00±52.33	4754.38±644.82
	Median (min.-max.)	600.00 (563-637)	4754.38 (4298-5210)
2019	Mean ± std. deviation	653.00±230.52	4708.29±584.92
	Median (min.-max.)	653.00 (490-816)	4708.29 (4294-5121)
Sig.		0.416	0.827

Table 4. *Correlation results of the relationship among age, number of ships served, and number of wastes collected*

			Year	Number of vessels served	Amount of waste collected
Spearman's rho	Year	r	1	-0.424	-0.283
		p	.	0.169	0.373
	Number of vessels served	r	-0.42	1	0.175
		p	0.169	.	0.587
	Amount of waste collected	r	-0.28	0.175	1
		p	0.373	0.587	.

that the p-values are not significant. However, as the number of ships served increases, the amount of waste collected increases.

7. Conclusion

Operations for waste management emerge as a secondary activity, since the main activities of ports are ship and cargo operations. All of the operations must be in harmony with the holistic scope of port management. This study evaluates the secondary activities of ports depending on their main activities. Within this framework, this paper compares the WRP of two important ports in İstanbul by considering their ship call, cargo handling, and waste reception data.

WRP is evaluated in two categories: the amount of waste received per ship call and the amount of waste received per cargo handled. Additionally, these evaluations are performed for each waste type. To evaluate the relation of these variables' statistical analysis, the Spearman correlation test, Kruskal-Wallis test, and Mann-Whitney U test are applied. The study shows that the amount of waste received per ship served is much higher at the Haydarpaşa port. The study approached from 2014 to 2019, and the number of ships serving and the amount of waste collected decreased. Furthermore, the comparison of waste reception performances of the two ports in the SoM using computed indices reveals a significant difference between the Ambarlı and Haydarpaşa ports. The findings shows that the type of ship is a crucial factor in waste generation. The adequacy of port reception facilities should be improved by considering the port size, waste type, and amount of discharge. Effective organization of waste reception is crucial for preventing illegal waste discharges. Encouraging shipping companies to separate wastes such as plastic, metal, and glass can reduce the pollution of recyclable waste in the marine environment and support the circular economy. As a semi-enclosed sea, the location of the SoM is geographically at a critical point, making it a hub for local and international ship traffic. Regulations, including the MARPOL 73/78, 2000/59/EC directive, and Turkish laws, have been established to protect the marine environment from ship-generated pollution, which significantly contributes to the prevention of marine pollution. However, ship-generated waste reception organizations should be improved with local rules in the SoM considering that it is a SEPA. An efficient ship-generated waste management plays a vital role in the sustainability of the SoM. The performance indices reveal that while the port size of Ambarlı (group 3) is higher than that of Haydarpaşa Port (group 1), the waste reception performance of Haydarpaşa is significantly larger than that of Ambarlı. This issue arises from the fact that general cargo ships undertake additional operations, such as cargo hold cleaning, in preparation for the next load, resulting in the generation of additional waste compared with container ships. Given the differences between terminal types, it is evident that there is no "one size fits all" policy approach, and mitigation strategies need to be tailored to the characteristics of each port. Therefore, improving the definition of environmental indicators by ports is important for environmental management. It should be noted that this study was conducted only on two selected ports in the SoM. Future studies may be required to investigate different types of ports, regions, and terminals in the SoM. Future research endeavors may expand the scope to encompass a wider array of port types, regions and terminals within the SoM, facilitating a more comprehensive understanding of waste management dynamics in this critical maritime region.

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